Main roles of GIS in ecological studies on small protected islands

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Introduction

Geographical information systems (GIS) have been operational for nearly thirty years; over this period, they have been improved and fitted to the needs of a public always more varied. They are based on the complementarity of four components: computer hardware, software modules, data and liveware (Maguire 1991). They are endowed with numerous assets for the institutions concerned by the environment and especially by its protection (Aspinall 1995; Bridgewater 1993). Because of their capabilities GIS technologies can be advantageously used in this context i) to perfect the protocols for field data collection, ii) to analyze and model the ecosystem, or iii) for the decision-making tools provided.

This paper is aimed at briefly highlighting GIS benefits to the knowledge of ecological processes occurring in small protected islands. Indeed, marine islets are complex environments because of the large number of physical, biological and anthropic phenomena interacting within and between the three geographical compartments constituted by the marine, intertidal and terrestrial domains. Understanding their global functioning and time-evolution is fundamental to allow administrator(s) to make decision.

Main roles of GIS in ecological studies

In landscape ecology studies the numerical processing of geographical information constitutes an extremely dynamic, scientific and multi-disciplinary pole (Haines-Young *et al.* 1993). The various reflections conducted deal with landscape ecology as a trans-disciplinary ecological and geographical science (Naveh 1991) within which the spatial dimension has a central position. In landscape ecology GIS provides one with the 6 following main functions (Stow 1993).

Database structure for storing, handling, analyzing, modeling and displaying ecosystems data over large area(s). The use of GIS technologies in ecosystem studies meets extremely logical criteria. Indeed, the numerous parameters and, thus, the complex geographical objects to be taken into account about coastal zones leads one to have recourse to data computerization (Ricketts 1992). Moreover, this composite geographical information can sometimes be analyzed only by a numerical computing power. Small islands are characterized by 3 interacting domains functioning at various space-time scales. The data to be acquired are thus multiple, even though the areas of concern are restricted. In addition, the fact that the researchers and administrators concerned by small protected islands work in network implies that they have at their disposal data easily linked to allow comparisons between various island systems with the aim of detecting any change in global climate.

Handling ecological data of various scales into a hierarchical structure. The space and time scales inherent to environmental processes necessitate to organize ecological data into a hierarchy subsequently stored into geographical databases. The hierarchical nature of environmental processes constitutes a very rich and interdisciplinary research field leading one to explore geographical object aggregation and disaggregation to grasp the scalar levels of a given process. On this topic a multi-scalar GIS can provide one with means to empirically assess scale changes in the structure of the environment (Raynal *et al.* 1996). To create a multi-scalar geographical database it has been suggested to organize spatial data into a hierarchy by using the *quadtree* method (Hansen 1996) based on the fitting of grid cells of different spatial resolutions.

Ground surveys. *One can also utilize GIS to elaborate a field-sampling or -operation scheme. For example, relief, nature of soils and vegetation often constitute the basic data used to define the place where study plots will be made to get a representation of the ecological diversity at a given site. This functionality is used above all by conservation institutions like the National Parks (Briggs and Tantram 1997). Another use of GIS technologies is the elaboration of intervention plan from a selection of sites meeting specific criteria.*

Spatial and statistical analysis of ecological distributions. The numerical nature of geographical data fits well statistical analysis whose first step automatically provides one with available general statistics in relation with geographical objects. At a higher level of analysis, most of the applications based on these methods aim at evidencing correlations between several environmental variables such as vegetation and land-use changes (Foster 1992), the effects of wildlife on vegetation (Johnston *et al.* 1993) or the characterization of habitats (Moses and Finn 1997). The information issued from these analyses is often utilized to monitor and compare environmental indicators (Goossens *et al.* 1993) or to test effectiveness of existing conservation designation (Bushing 1997). Spatial and statistical analysis is essential to understand the processes occurring in a coastal area undergoing both ‘vertical’ interactions within the marine, intertidal and terrestrial compartments, and ‘horizontal’ inter-relations between one of them and the others.

Remote-sensing integration. The integration of remote-sensing into GIS has provided environmental studies with a genuine investigation power (Robin 1995). Nevertheless, it is only a potential source of data among others whose use finds its justification in the aim to be reached. At the spatial scales at which satellites observe the Earth, one cannot seriously envision to use satellite imagery to monitor the dynamics of small environments on short time-scale, *e.g.* every 5 years. To detect space changes in these areas, data-acquisition and-analysis scales must be greater than 1 : 5 000, with a measurement precision of 1 meter. Today, numerical orthophotographies or aerial remote-sensing (CASI) can punctually overcome the too low resolution of satellite sensors; so, one can use them to monitor shallow marine waters, intertidal and terrestrial areas.

Modeling. Modeling is integrated into a GIS to put models into a consistent information systems allowing the development of satisfactory and multi-disciplinary simulation tools (Steyaert and Goodchild 1994). In this prospect GIS actions in modeling take place at two levels. First, geographical information are used to calibrate models in order to ensure a relevant forcing and provide one with realistic results. Then, the digitized geographical data are introduced for validation step since GIS can handle sets of spatial data required to analyze the evolution of the studied system. For marine islets, modeling enables one represent spatially continuous parameters, *e.g.* currents, tide, atmospheric phenomena, characterized by a high space-time variability.

Main functions of GIS in a planning context

Protected areas are managed to ensure the conservation of areas and species. With the help of GIS technologies their administrators develop a set of activities among which one can mention i) environmental data handling, ii) local planning, iii) countryside monitoring and management (Briggs and Tantram 1997).

Environmental data handling

Handling spatial data of varied sources and natures is of prime importance for any institution concerned by environmental protection. The use of a digital medium instead of an analog one increases decision-making efficiency through the guarantees of safe and high-quality data along with easy access to information and increased analysis capabilities.

Local planning

To make decisions the administrators of protected areas often use maps drawn up from a lot of spatial data; such documents constitute a visual help essential for field staff, an aid for drawing up inventory as well as a mean of information and communication. In a short access time GIS allows one to store data from various origins, facilitates the design of maps meeting specific needs, *e.g.* scale, typology, and enables one to spare time in the production information through a possible automation of design. All these characteristics not only increase map production, but also improve their quality by a better adequacy with the objectives to be reached.

Countryside monitoring and management

GIS can be used to settle and implement field monitoring schemes, to detect and model ecological changes and simulate evolution or impacts.
<u>Setting monitoring scheme</u>. GIS technologies can be used to localize the sites to be inventorized prior to the field stage on combining specific data stored in the database to determine the ecological variables to be sampled. After the mission, the integration of the geographical co-ordinates of study plots permits one to better manage experimental sites. Within this framework, and thanks to the technological improvements of GPS, the localization as near as one meter of study plots is made possible, which reduces the risks of mistakes in the recording of spatial information. Within this operational context GIS

can also help the piloting of experimentation plan through the search for the sites meeting the criteria required to set the operation or focus actions onto habitats either vulnerable or with a high heritage value.

Change detection. Areas are protected because, at a given time, they are endowed with an exceptional heritage value. But, these environments like all the other ones, are dynamic and undergo natural and anthropic constrains inside and outside the protected area. These perturbations can thus change the protected object, and eventually lead to its disappearance. So, it is fundamental for the administrator to quickly detect any time-change affecting the area of concern in order to eventually take action. This ability to detect change is therefore crucial for an efficient management for it allows one to establish surveys, analyze the change-inducing factors and predict potential changes.

Impact and evolution simulation. The simulation of impacts and changes on environmental diversity enables the implementation of management strategies liable to avoid or reduce some negative aspects. Their space-time modeling from the information stored in a database can be very helpful to make a realistic synthesis of the evolution of any ecosystem faced to perturbations.

Conclusion

Protected small islands are complex systems characterized by three interacting geographical domains. Like all coastal zones, the understanding of global ecological processes is based on a great variety of geographical data collected at many spatial and temporal scales. It also implies the use of technological tools to input, store, analyze, display and handle this spatial information. GIS provides one with the possibilities of understanding how and why the ecological processes interact. The use of such a system may lead to a better knowledge of the functioning and evolution of the ecosystem, and consequently to the development of suitable management decisions. In addition, a network organization reinforces the necessity of developing common protocols and tools to comparatively assess the functioning of various Mediterranean, Atlantic and Pacific islets and the effects of global climate change(s).

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